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PRACTICAL APPLICATIONS
of
Geology and Physiography

For USE in the LABORATORY and CLASSROOM

Herdman F. Cleland

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PRACTICAL APPLICATIONS

OF

Geology and Physiography
FOR USE IN THE LABORATORY AND CLASS ROOM

Herdman F. Cleland, Ph.D.
PROFESSOR OF GEOLOGY, WILLIAMS COLLEGE
AUTHOR, PHYSICAL AND HISTORICAL
GEOLOGY, ETC. ETC.

Excelsior Press
North Adams, Massachusetts

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PREFACE

Every teacher of general geology endeavors to point out to his first year students not only the cultural value of the subject but its practical value as well. The cultural worth of Geology is self-evident but, as it is often difficult for the teacher to find questions that bring out the practical value of the subject, the student too often fails to appreciate its importance in this particular. It is to supply this need, which has probably been felt by all teachers of Geology, that these questions are brought together. They can be used in the class room or to enliven laboratory exercises.

It is realized that the list is far from complete; that it will be necessary in a later edition to modify some of the questions in order to make them clearer without suggesting the answer; and that some would better be omitted. Consequently it is hoped that every teacher who uses these questions will formulate others which may be suggested by his own geological experience and reading, and that he will send these to the author and compiler together with his criticisms for the improvement of those presented here.

So many of these questions have been contributed by other geologists that the writer hesitates to take the credit of issuing them. Professor Andrew C. Lawson, for example, of the University of California, has contributed so many that his name might well appear on the title page as author. Excellent questions have also been contributed by Professor J. Austen Bancroft of McGill University, by the late Professor J. Barrell of Yale University, by Professor L. C. Glenn of Vanderbilt University, by Dr. E. M. Kindle and Mr. L. M. Burling of the Canadian Geological Survey, by Dr. E. H. Sellards of the University of Texas, by Mr. C. A. Hartnagel of the New York Geological Survey, and by Mr. J. B. Tyrrell of Toronto. Some of the illustrations are original, but most of them have been adapted, or taken without change, from geological publications.

A word of warning about the use of these questions may not be necessary but can do no harm. If no answer is accepted from a student until he has shown that he possesses a knowledge of the geological principles necessary for the solution of the problem and that he has arrived at his conclusions after careful thought, they will be found of very great value. If on the other hand, the teacher is satisfied with answers that are little more than guesses, the questions would better not be used.

Herdman F. Cleland

Williams College
Williamstown, Massachusetts
August 4, 1920

PART I

THE APPLICATION OF GEOLOGY IN ENGINEERING, ARCHITECTURE, AND AGRICULTURE

CHAPTER I

ARCHITECTURE

I. BUILDING STONES

1. It is stated that Somerset House in London and York Minster, both of which are built of limestone, are much more decayed on the south than on the north sides. Why is this?

2. In New York and other cities of the eastern United States many buildings are faced with a red sandstone, the blocks of which are laid on edge, i. e., the bedding planes are vertical. An examination of these stones often shows that the "face" has been split off in leaves, producing an unsightly surface which necessitates either new blocks of stone or redressing. Tombstones of this same material are similarly affected, the broad sides of many being split off in leaves, frequently obliterating the inscriptions. How may this be explained?

3. It has often been noticed that stones quarried in the autumn are more likely to disintegrate than those that were quarried in the summer. Why is this?

4. What would have been the effect of the weather on the Egyptian obelisk, now in Central Park, New York City, if it had been erected in southern California instead?

5. Would a given stone wall stand longer in the Province of Quebec or in the State of Mississippi? What are the principal agents of weathering by which it would be ultimately destroyed in each place?

6. A model of the Liberty Bell was made of sandstone and placed in the National Museum in Washington. When the Museum became crowded, the model was set up on the lawn in front of the building. In a few months the surface of the rock became rough, the inscription on it became faint, and

its surface became covered with blotches of a white efflorescence. On examination it was found that the sandstone possessed a calcareous cement and contained marcasite (FeS_2). Why did the rock weather rapidly? How were the white blotches on the exposed surface formed? What lesson can be learned from this in the selection of building stones?

7. Examine the gravestones in an old cemetery. Note kinds, dates when erected, relative amounts of weathering of the different kinds as compared with one another and of the same kind as dependent upon exposure to the several agents of weathering. Which is best adapted to inside building use? Outside use? What were the sources? What is the relative cheapness in working, durability under exposure, and attractiveness?

8. The Houses of Parliament in London are built of Magnesium Limestone (dolomite) and already decay has proceeded so far that much of the carving has been obliterated.

The Museum of Practical Geology in London, built about the same time, is also constructed of dolomite and scarcely a defective stone can be found in the building. The quarries from which the stones were obtained are only about eight miles apart. The stone used in the Parliament Buildings was not selected after a careful geological examination, while that used in the Museum was chosen after a careful study. What criteria should guide one in the selection of limestone for building purposes?

9. Blocks of slate left unsplit for several months lost their property of ready cleavage and became useless. Why?

10. Slates of uniform shade when placed on a roof were found in a few years to vary much in color. Why?

11. Why is granite or concrete preferred for curbstones to laminated rocks, such as a laminated limestone?

12. Slate, limestone, and marble are most readily sawed and finished if kept moist from the time of removal from the quarry. Why?

13. What is the effect of fire on granite? On limestone?

14. Before Hilgard Hall was built on the Campus of the University of California the granite proposed for its construction was examined in the quarry by a geologist and approved by

him. What are the common defects of granite which detract from its value as a building stone?

15. Certain sandstones which are otherwise soft are very hard at their outcrops due to the deposition of silica in the pores of the rock for a fraction of an inch in from the surface. Explain.

II. FOUNDATIONS

1. Houses with shallow foundations built on hillsides are frequently cracked as the result of "hillside creep." Why is this and how can the difficulty be overcome?

2. What relation does latitude bear to the depths of the foundations of houses, and why?

3. Why is it generally safe to erect heavy buildings on till but unsafe when beds of sand occur in the till? What is the origin of the sand? This condition occurs at Toronto.

4. If a landslide should originate in a city built on a hill, how could it be permanently stopped?

5. In California there are two seasons,— wet and dry. What is the effect of this alternation of wet and dry conditions on the soil? How does it affect the planning of foundations?

6. If you were building a concrete foundation for a building in the latitude of Ohio, would you make the sides smooth? Would any harm be done if the sides were rough? State your reasons fully. If a stone in the concrete projected a few inches from the outer side of the foundation would you smooth it down or leave it projecting? Why?

III. BUILDINGS IN EARTHQUAKE REGIONS

1. After the Messina, Sicily, earthquake the Italian Government made certain recommendations: (1) concerning the construction of buildings, (2) concerning the height of buildings in different portions of the city, (3) concerning the parts of the city on which no building should be erected. State in detail the reasons for these recommendations.

2. In the Avezzano, Italy, earthquake of 1916, there was great destruction of life and property. The high cost of quick-

lime was an important indirect cause of the loss of life. How may this be explained?

3. An account of an earthquake appeared in a daily paper in which it was stated on good authority that at least 30,000 lives had been lost. From this brief statement tell: (1) the probable cause of the earthquake; (2) if landslides occurred, where they occurred and why; (3) what kinds of houses were demolished and why; (4) where the area of greatest destruction was located. How sure are you of your inferences?

4. A house constructed of stone was badly damaged by an earthquake shock, while another one nearby of the same construction and materials escaped with little damage. Give the possible explanations.

5. Why do brick chimneys break off at the roof line in time of earthquake shock?

6. What portions of San Francisco suffered most severely from the shock of 1906? What was the cause of the exceptionally heavy damage in these districts? How may the danger from destruction in these districts (those portions of San Francisco which suffered most severely from the earthquake) be minimized?

7. At the time of the California earthquake of 1906 some buildings of Stanford University were completely wrecked and many were injured, but the Museum which was built of reinforced concrete suffered no serious damage. What was the reason for this immunity?

8. If a geologist had been asked to co-operate with the architects in the planning of the buildings of Leland Stanford University what would have been his report in regard to the wisdom of selecting the present site, and of the type of building construction which was employed? (See the report of the California Earthquake Commission.)

9. To what extent does heterogeneity of structure render a building susceptible of damage by earthquake shock?

10. What is the best type of earthquake-proof residence?

11. During earthquake shocks small houses may be shifted off their foundations by the horizontal jerk. How may this be prevented?

CHAPTER II

WATERWAYS

I. Rivers

1. In canoeing on a river such as that shown in figure 1 what course must one take? Draw sections A-A, B-B, C-C to show the probable configuration of the banks and the depth of the water.

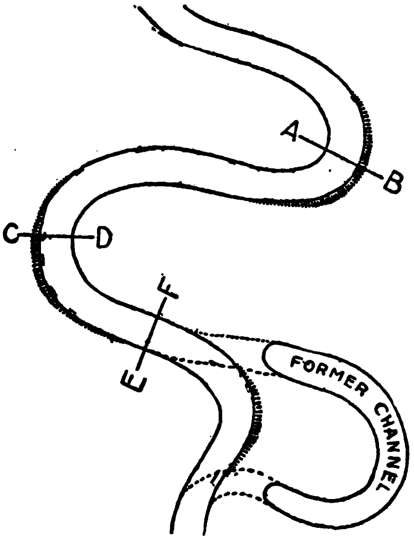

Fig. 1

2. In a meandering river such as the Mississippi, where in figure 1 would bars form, and where, consequently, would steamboats have the most difficulty in finding a channel? Do bars in such cases form more readily during rising or falling stages of the river?

3. Fifty years ago Mompox, Colombia, an old Spanish city, stood on the banks of the Rio Magdalena. It is now twenty miles from the river. Construct a diagram to show how this change was brought about.

4. Why is the Mississippi River so much deeper at New Orleans than near the sea and how would you go about it to obtain a navigable depth in this shallower portion: (a) if you let man do all the work; (b) if you made the river help you? Which of these two methods would be the more permanent?

5. Tennessee and Arkansas have occasional lawsuits over their boundary. Why? Consult maps.

6. A stream is undercutting its bank. What is the best device to prevent this?

7. When such a river as the Mississippi undercuts an alluvial bank so as to cause caving, will the caving be more active as the river rises or falls?

8. What is the effect on the velocity of a stream of straightening the meanders by artificial means?

9. In shallow, navigable rivers, such as the Volga the sands are continually shifting and make the channels available for navigation uncertain. What is the cause of the shifting? Is there a remedy?

10. To what is due the obstruction of the Columbia River between Portland, Ore., and the Dalles that necessitates a canal for steamers?

11. Why were Geologists justified in opposing the recommendation that $50,000,000 be expended in dredging a channel for ocean going vessels from Albany to New York City? Study maps before attempting an answer.

12. Is there any difference in the discharge of a river at a given stage when rising and when falling?

13. What shape has a cross-section profile of a river when rising ? When falling? What effect on drifting materials?

14. The high water stage of the Saskatchewan, Canada, is in the summer and may occur in a hot, dry period. Explain.

15. Is it safe to assume that the bottom of a river at a ford lies at the same level in time of flood as in normal times? Give reasons.

16. A meandering stream with sandy bottom may require bridge piers to be sunk very deeply; in the case of the Platte River of Nebraska, to upwards of 90 feet. Why? Should the maximum depth of the channel be measured during the flood or slack water period?

17. A stream is undermining bridge piers. What is the best device to prevent this?

18. Why are the bottoms of broad channels of a river generally covered with fine sediment while some of those of narrow channels are covered with coarse gravel? Which would be safe to ford in an automobile?

19. What streams will generally give the more solid footing for a ford, a sluggish or rapid stream? The narrow or wide part of the stream? A strongly curving or a straight course? Give reasons.

20. The accompanying figure (Fig. 2) is a cross-section of Culebra cut of the Panama Canal showing the surface before and after one of the slides. Give the cause of the slide. When will the sliding cease?

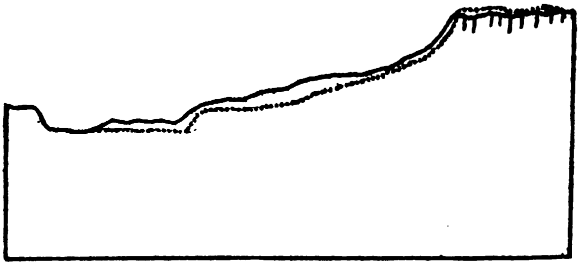

FIG. 2—(MODIFIED FROM BUREAU OF MINES)

II. SEAS AND HARBORS

1. Indicate by a diagrammatic sketch how you would place piers to protect a poor harbor on a coast where the drift of the shingle has a definite direction. Give your reasons.

2. What natural processes contribute to the cost of maintaining a natural harbor?

3. Hudson Bay is so shallow that an elevation of 500 feet would convert nearly all of it into boggy ground like that on its southern shores. There is a gradual deepening of the water towards Hudson strait, however, where channels with depths of 200 and occasionally of 300 fathoms are found. (Coleman, America). How do you account for the shallowness of the Bay and the presence of the channels?

4. What propels the Hawaiian native when he rides his surfboard toward the shore on the crest of a wave? With no effort other than the one to preserve his position and equilibrium, he moves shoreward at great speed.

5. What natural features unite to make a good harbor? Give examples, and explain why.

6. What, in general, is the origin of landlocked harbors?

7. Why was the city of San Francisco located where it is rather than on the east side of the Bay?

8. What is the origin of the islands in San Francisco Bay.

9. Some Indian mounds on the shores of San Francisco Bay have their base below tide level. What is the geological significance of this fact?

10. Why is the water of San Francisco Bay deepest in the Golden Gate?

11. Explain the origin of the bar outside the Golden Gate. Why is it crescent-shaped? (See maps of the Coast and Geodetic Survey).

12. What is the relation between the reclamation of the marsh lands of the Great Valley and the silting up of San Francisco Bay?

13. Explain how observations on asymmetric ripple-marks, the accumulation of sand and shingle alongside of groins, and other kinds of data, will indicate the prevailing direction of shore currents on sea and lake shores.

14. Why have repeated dredgings of the bottom of the St. Lawrence River (not the tidal portion) failed to yield the depth of water desired? It is not due to resilting.

15. In many places the gentle seaward slope of the coastal plain of Hudson Bay continues below water, so that the space between the high and low tide may be miles in width, and even canoes with but a few inches of draught must keep miles from shore when following the coast, to find depth enough of muddy water for navigation. (Coleman, America) Explain the extreme shallowness of the water.

16. What has glaciation had to do with the configuration of the harbor at Victoria, B. C.? Consult map.

17. What geological conditions affect the bridging of San Francisco Bay? See San Francisco Folio.

18. What geological conditions affect the tunnelling of San Francisco Bay? See San Francisco Folio.

19. What is the tidal prism of San Francisco Bay? What agencies tend to affect its size? How does its size affect the permanence of the entrance to the Golden Gate?

III. LAKES

1. The most extensive lake region in the world, one similar to those of Scotland, Finland, and Scandinavia, but on an immensely larger scale occurs on the Archean Shield of Canada, that great mass of crystalline rocks about Hudson Bay. State all the elements in the production of this condition.

2. Canoe routes can be followed in almost any direction for hundreds of miles across the "rocky lake" type of country so prevalent on the Archean Shield of Canada. A canoe may be launched on the north shore of Lake Huron or Superior, or from some little railroad station beyond Lake Superior, and worked north and west to Hudson Bay or Lake Winnipeg, with few portages of more than a mile or two, often for many miles with nothing more than a "drop over" from one water level to another. (Coleman, America). State the factors which brought these conditions about.

3. The valley of the Schroon River in the Adirondack province of New York is bordered, and in places filled, to a width of a half-mile or more with stratified sands and gravels. These deposits are of approximately equal altitudes. From this evidence what would you conclude was the origin of the sand flats? What is the origin of Schroon, Paradox, and Brant Lakes? Of what economic importance are the lakes and terraces?

4. What types of lakes may be formed during the development of stream valleys? Are they shallow or deep? Are they of economic importance? Give examples of each type.

5. What types of lakes are formed as a result of glaciation? In what ways were their basins formed? Of what economic importance are lakes of this origin? Compare the lakes north of the Ohio River, with those south of it as to number, size, depth, and origin.

6. How are lakes formed during the development of shores? Cite examples. Economic importance?

7. Why are there no natural lakes in the high mountains of North Carolina?

8. Why have swamps and lakelets formed in the last few decades on the flood-plains of many streams in the piedmont region of the South? Why have such lands largely become unfit for cultivation?

CHAPTER III

WATER SUPPLY

I. WELLS

1. At Denver, Col., some four hundred wells were sunk in an area forty by five miles and an abundance of flowing water was obtained. Account for the fact that in about fifteen years many of the wells ceased to flow.

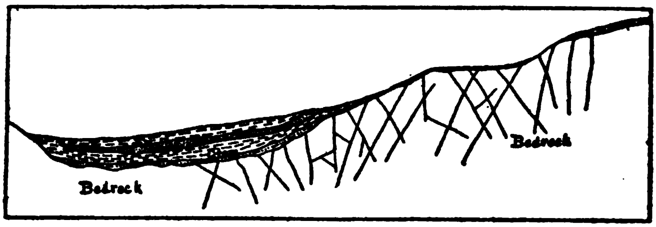

FIG. 3—MODIFIED AFTER U. S. GEOLOGICAL SURVEY

2. In a region in which the rocks have the relation shown in the diagram (Figure 3) where should wells be sunk? Would any be flowing wells? If so, where?

3. Account for the fact that fresh artesian water is in some places obtained on sand reefs separated from the mainland by salt water. Construct diagram.

4. Account for the fact that at Colonial Beach, Va., the sinking of one well on the water front has stopped the flow of a neighboring well on ground a few feet higher.

5. In the following diagram (Fig. 4) indicate the position of the water-table (1) after a wet season, and (2) after a dry one. To what depth should a well be dug and under what condition would the well yield a sufficient quantity of water for the purposes of a farm?

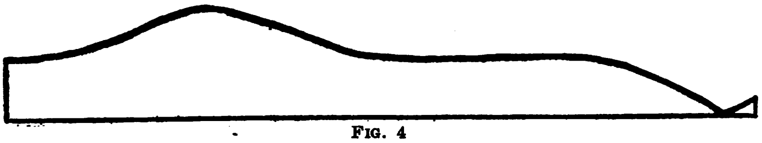

FIG. 4

6. Country houses are often built facing a down slope to get the view. The well is sunk in the front yard. The barn-

yard and out-buildings are back of the house, perhaps on a higher slope. Where should the well be located? Does the fact that the house intervenes form any protection or may the area of the house protecting the subsoil from rain serve as a guide to direct underground drainage from behind the house toward the well?

7. Construct a diagram to show the depths to which wells must be sunk in different parts of a mature region.

8. Why are alluvial fans in a desert often the sites of oases? How does the soil of an oasis compare with that of other parts of the fan?

9. Hypothetical geologic maps presenting problems in locating well sites.

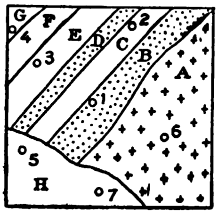

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FIG. 5

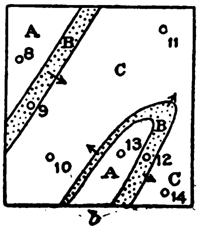

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FIG. 6

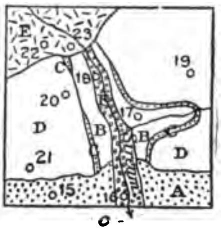

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FIG. 7

GREGORY'S MILITARY GEOLOGY—COPYRIGHT YALE UNIVERSITY PRESS

Figure 5. Area 10 miles square; nearly level. A to H are outcropping formations in the order of their age, A being the oldest and H, the youngest. The contact between A and B and the contacts between H and the older formations are unconformities. A is granite; B to G form a series of beds that dip about two hundred feet to the mile toward the northwest. B and D are water-bearing sandstones, and C, E, F, and G, clayey formations. H is a clayey formation that has a maximum thickness of one hundred feet.

Problems: Forecast the results that will be obtained by sinking wells at localities 1, 2, 3, 4, 5, 6, and 7. Draw cross-sections to illustrate your predictions. (Military Geology.)

10. Figure 6. Nearly level area. A, B, and C are outcropping formations, A being oldest and C youngest. B is water-bearing sandstone; A and C are shales which will not yield water. The arrows show the direction of dip

Problems: Forecast the results that will be obtained by sinking wells at localities 8, 9, 10, 11, 12, 13, and 14.

What is the unknown factor in these problems? Draw cross-sections to illustrate the unknown factor and your predictions. (Military Geology).

11. Figure 7. Area dissected along the streams, elsewhere only gently undulating. A to F are outcropping formations in order of their age, A being oldest and E and F (which were formed at the same time) being youngest. A is an ancient quartzite. B, C, and D constitute a conformable series of nearly horizontal beds resting on an irregular surface of the quartzite. B is impervious; C is a good aquifer except near the outcrop, but it is locally absent; D generally yields small supplies. E is boulder clay with interbedded gravel lenses. F is gravelly glacial outwash.

Problems: Forecast the results that will be obtained by sinking wells at localities 15, 16, 17, 18, 19, 20, 21, 22, and 23. Draw cross-sections to illustrate your predictions. Military Geology.)

12. A manufacturer in Connecticut decided to erect a factory in a certain place but was obliged to choose another spot because of the soft condition of the ground which made the cost of a stable foundation prohibitive. He consequently erected a building a short distance away from this site. A well was sunk in the new location and, for a number of years, a large quantity of water was daily pumped from the well. After several years an addition to the factory was necessary and it was found that the rejected site now afforded a stable foundation. Explain.

13. Where water is being pumped continuously from a well the level of the water is lowered. Draw two sections at right angles to each other through the well to illustrate the configuration of the water-table under such forced draft.

14. In San Francisco Bay and in the salt marshes which fringe it, wells have been sunk which yield fresh water rising above sea level. Enquire into the geological structure of the basin in which the bay lies and explain this supply of water (See U. S. Geol. Surv., San Francisco Folio, No. 193).

15. Water standing in wells on the east side of San Francisco Bay fluctuates in level with the rise and fall of the tide,

but the tide in the wells lags after the tide in the Bay. Does this mean that the sea water is in contact with the fresh water? If so why is the fresh water not contaminated? (See U. S. Geol. Surv., San Francisco Folio, No. 193).

16. When and why might a well on the shore of Chesapeake Bay flow at certain times of the day, but not at others?

17. Draw a diagrammatic cross-section of a typical alluvial fan, e. g., the fan at the mouth of San Antonio Canyon, Southern California, (Cucamonga Quadrangle) and indicate the position of the underground water.

18. Artesian water is found in the lower part of the great alluvial fans which have been built up in the broad valleys of California where torrential streams enter them from the mountains. In passing up the slope of such fans toward their apex what geological line limits the area of artesian supply?

19. Draw a section through the same fan parallel to the surface, say at a depth of two hundred feet, indicating diagrammatically the structure of the deposits and the storage of the water.

20. At the toe of the alluvial fans in the arid region of Southern California there are moist places called cienegas where certain kinds of vegetation thrive throughout the summer, but where the soil is highly alkaline and in many cases shows an efflorescence of alkaline salts. Explain the source of the moisture and the cause of the alkalinity of the soil.

21. In such alluvial fans as are referred to, in the above questions neighboring wells may get their most abundant supply from different depths. Explain this fact.

22. Two miles east of Santa Rosa, California, on a flat, alluvial plain there was a pool of fresh water just flush with the surface of the plain having no overflow and no streams flowing into it. On pumping so that the surface of the pool was lowered about fifteen feet it steadily yielded 3,000,000 gallons per day. Explain this yield from a pool having no overflow.

II. SPRINGS

1. It is often stated that springs occur on the tops of hills. Are most of such statements correct? Give reasons for your opinion. Are there exceptions? Explain.

2. In the diagram, figure 8, is shown the location of small villages in France, near Paris, situated where springs issue. On these springs local water supply for centuries has been dependent. Why do the springs occur in these places? State all of the conditions.

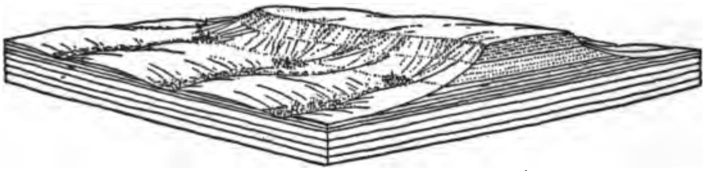

FIG. 8—AFTER W. M. DAVIS—HANDBOOK OF NORTHERN FRANCE

3. In a region such as that shown in figure 9 where is a spring likely to occur? May a spring flow from the left side of the hill?

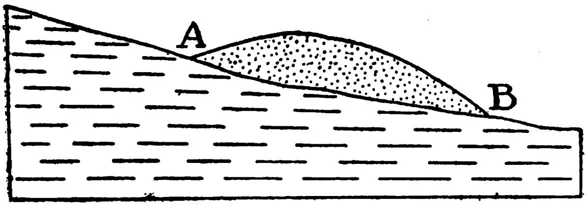

FIG. 9

4. During which stage of an erosion cycle is the water-table farthest from the surface? When is the run-off greatest?

5. Account for the fact that the vast lava beds of eastern Washington and Oregon, and of Idaho, form important water-bearing strata.

6. In some places springs occur at a uniform or a gradually changing altitude on the sides of a valley. Explain why.

7. In some regions springs occur along definite lines or a series of lines. What geological conditions will give rise to this linear arrangement?

8. In regions covered by basalt many springs deposit calcareous tufa, or travertine. Explain.

9. On many ridges springs are abundant on one side and absent on the other. What structural conditions may determine this unequal distribution of springs on the two sides of a mountain ridge?

10. At Steamboat Springs, Nevada, boiling water issues from a crack a mile long in an embankment of siliceous sinter. The abundance of the water varies with the seasons. What is the source of the water, the source of the heat, and the source of the silica?

11. On the face of the Niagara Escarpment in Ontario, springs are common at the base of the Medina sandstone. Enquire into the geology of the escarpment and explain the appearance of the springs at this horizon. (See U. S. Geol. Surv. Niagara Folio, 190.)

12. The flood-plain silts and sands of the Salinas River, California, are yellowish in color. At the time of the earthquake in 1906 hundreds of craterlets were formed on the flood-plain from which were ejected blue silts and sands, but no yellow sediments. What may be inferred from this as to the chemical character of the ground water below the flood-plain?

III. STREAMS

1. Why is the average mineral content of rivers in semi-arid portions of California generally several times greater than that of humid regions. What effect has this on their value for irrigation?

2. The promoters of an extensive irrigation scheme for western Canada built a ditch through a plain underlain in places by *loess*. It would not hold water until lined with concrete. Could this have been foreseen after a geological examination? If so what recommendations would have been made?

3. Certain streams in California, e. g. Santa Ana, disappear in the sands of the channel in which they flow but appear again lower down and flow as surface streams. Explain this behavior.

4. In some water supply ditches in California there is greater loss of water by leakage where the ditch is cut in hard rock than where it is cut in soft earth. How is this explained?

IV. MISCELLANEOUS

1. Under what conditions may sink holes become the sites of lakes? In Florida such lakes sometimes disappear. What means should be taken to restore them?

2. A commission appointed by the city of Pittsburgh recommended the building of seventeen reservoirs in the upper courses of the Allegheny and Monongahela Rivers at an expense of $20,000,000 in order to reduce the floods to which that city is subject. Was the recommendation a good one? What influence would such reservoirs have upon the level of the river in times of drought?

3. What is the origin of crater lakes? Why cannot a crater lake usually be drawn upon as a source of permanent water supply?

4. In 1906 at the time of the earthquake the main supply pipes of San Francisco were broken and the city was destroyed by fire for lack of water. What precautions based on geological considerations may be adopted to ensure the safety of such water supply?

CHAPTER IV

RAILROAD AND HIGHWAY ENGINEERING

I. Railroad Engineering

1. From the surface downward, London, England, is underlain first by porous materials, second by the impervious "London clay", and this in turn, by other wet strata. One underground railroad was dug near the surface and another in the "London clay". Which "subway" is the drier and more healthful?

2. During what part of the erosion cycle is railroad building most difficult? Why then are railroads built in regions that are in this stage of the cycle?

3. A railroad in Alaska has been built across 5 1-2 miles of the Allen Glacier. What future difficulties may be expected?

4. Enumerate the reasons why railroads have lost heavily in the past because of their failure to receive geologic advice in determining the route to be followed.

5. A railroad train in Brazil was wrecked by a landslide where the dip of the rock is that shown in the diagram Fig. 10. Why did the slide occur?

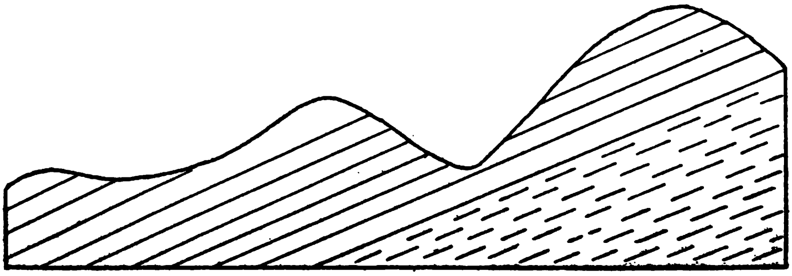

Fig. 10

6. Why are the bottoms of telegraph poles in parts of Arizona protected by cement or in other ways?

7. In Northern Ontario the great clay plain is level, partly because the clay underlying it is so unctuous that it will sink to a level. In spite of this the railroad engineers have built on it heavy stone and concrete abutments for their bridges beside the channels of the streams, and in many places these have sunk and slid together at the bottoms. Such abutments are still being built and the bridge engineers do not yet know

that geologists could assist them in their work. What recommendations should be made where such conditions exist?

8. On the western plains the valley sides of many rivers are covered with broken rock carried by rock slides. This slidden rock may not be recognized as such and abutments built on it often cause the rock to continue to slide into the valley carrying the abutments with it. It is perhaps evident why a geological examination should be made, but what should be done to prevent further movement when abutments are to be built?

9. In the building of railroad fills in portions of Canada enormous quantities of loose material have been dumped into lakes and swamps underlain by smoothly glaciated rock. State what difficulties probably resulted and what should have been done.

10. Floods in the desert often wash out railroad tracks and bridges. What are the physiographic features of localities where such washouts may be expected?

11. What is the best material for roadbed ballast?

12. If a contemplated new railway had the choice of passing through either a gold mining country or a region where coal seams were known to exist, which in general would be the preferable route?

13. Look at a map of northeastern Pennsylvania. Does the Lehigh Valley R. R. from Easton to Sayre show a dependence on the river systems? What are the advantages? The disadvantages? The Lackawanna railroad has recently spent many millions of dollars in laying new tracks from Scranton, Penn., to Binghamton, N. Y., at an elevation of one hundred to three hundred feet above the old track. What was the cause of the great expense? What justified it?

14. The south side of Feather Canyon, Calif., is steep, and is subject to landslides and snowslides. There is much water seepage and the snow lingers in spring. The north side is dry and is less affected by snow, seepages, and slides. Why is this? Which is the preferable side of the canyon for a railway location?

15. The Central Pacific Railway track between Suisun and Benicia, California, crosses a marsh into which it has repeatedly sunk; and it has required a vast amount of filling to secure a stable roadbed. Under what conditions was the marsh formed? Could the conditions encountered by the railway engineers have been foreseen?

16. Under what geological conditions in general is a tunnel through the shoulder of a hill preferable to a curve on the contour?

17. The Rogers Pass tunnel of the Canadian Pacific Railroad although driven at a depth of a mile below a snow and ice covered peak encountered no flow of water. How do you account for the dryness of the rocks?

18. Under what geological conditions is an open cut preferable to a tunnel?

19. The railway bridge over the Pajaro River at Chittenden, California, crosses the San Andreas fault, and was displaced on its abutments at the time of the 1906 earthquake. How may engineers be advised to deal with such a situation?

II. HIGHWAY ENGINEERING

1. What are the essentials of the foundation of a good highway?

2. What steps should be taken to insure the permanence of a highway over flat, wet ground?

3. How may highways be rendered impervious to water so that their foundations may be kept dry?

4. What rocks yield the most dust under attrition on a highway?

5. What kinds of soils make the best roads without macadam or concrete?

6. What rocks used in macadam make most mud in wet weather?

7. What kinds of rock crush most easily for macadam?

8. Different rocks break differently when crushed. What shapes of broken rock pack best in a macadam road?

9. Why is concrete preferred to macadam in highway construction?

10. How does concrete compare with macadam in the matter of repair?

11. A gravel road in one part of a New England village has to be repaired each spring and is little more than a ridge of mud after a few weeks use. Another gravel road in the same village is dry throughout the year and requires little repairing. The gravel of one road comes from a stream bed and that of the other from a delta terrace. Why is one road bad and the other good?

CHAPTER V

MINING ENGINEERING

1. Streaks of soft, weathered rock are sometimes encountered in mining and tunnelling which give much trouble since they require timbering. Mention a number of ways by which such streaks are formed.

2. In tunnelling and mining operations, where rock-work enters as an important factor, do joints facilitate or hinder the operation?

3. If in a glaciated region, you were to find within the drift scattered boulders containing some mineral of economic value how would you proceed in an attempt to locate the deposit from which the boulders were derived? Evidence such as this led to the discovery of a deposit in Canada.

4. Why is the hardness of a mineral often a better test in its identification than its color? Give examples.

5. Why do pyrite concretions lower the value of coal?

6. If a well were dug in the bottom of a former salt lake, what would be the theoretical order of the deposits encountered? Would this theoretical order necessarily occur? If not, why not?

7. Does the anthracite coal in Pennsylvania occur in anticlines or synclines? Why?

ADVANCED QUESTIONS

1. How is it possible for a paleontologist to state that certain iron ore beds in New York and Alabama are of the same geological age? Explain fully.

2. You have to plan a tunnel in inclined strata and have a choice of direction. What angle with the strike of the beds is the most favorable for excavation?

3. In some of the California drift mines the floors of the tunnels rise and have to be cut down once or twice a year to keep the gangways open. What is the cause of this? What has happened to the bedrock since it was buried by the auriferous gravel?

4. At the Argonaut mine, California, the hanging wall has been apparently displaced upward one hundred and twenty feet in the direction of the dip which is northeast at an angle of 67°. The fluting and striations on the walls of the vein, however, rake down to the northwest at an angle of, say, 25° with the horizon. What is the actual displacement?

5. A tunnel driven east in a vein encountered a fault having a strike of N.75° E. The vein dips S. 60°. The fault dips S. 70°. The miners could not find the vein beyond the fault. How would you look for it?

6. If a copper vein consisting chiefly of quartz with intermixed masses of chalcopyrite is altered by the weather and underground water, what minerals will probably be found in different parts of the vein from the top down? Diagram.

7. Why are galena and sphalerite more or less segregated at different levels in the mines at Joplin, Mo.?

8. At Nanaimo, B. C., coal mines which are worked far below the seas are so dry that they have to be sprinkled with water as a precaution against dust explosion. Would you infer that the rocks are dry?

9. A mine was pumped from the six hundred foot level for some years. On deepening the mine a larger pump was installed at the nine hundred foot level, but the amount of water lifted was but slightly greater than that at the higher station. Where does the water come into the mine? How could the pumping bill be reduced?

10. If you brought to a paleontologist a specimen of rock containing the fossil Phacops rana and told him you thought coal would be found just beneath that rock, what answer would he be sure to give you and how would he justify his answer?

11. North of Suisun, California, a Portland cement plant was established because limestone appeared in large areas over the hill. It was subsequently found that the limestone was a travertine which occurred as a veneer on the hillside and limestone is now hauled to the plant by rail a distance of over seventy-five miles. What is the relative cost of freight on limestone for a series of years and geological advice in the first instance?

12. Some ores are enriched by addition of compounds of the metals and some by abstraction of gangue. Cite cases of these kinds of enrichment.

13. In North Wales a bed of black manganese ore was mined out and the mine abandoned. It was subsequently found that the bottom of the abandoned mine was in rhodochrosite. What is the probable relation of the black ore to the rhodochrosite and why was the mine abandoned?

14. In the Ruth mine, Ely, Nevada, the boundary between the gossan and sulphid ore is very sharp but extremely irregular. Explain the cause of the irregularity.

15. At Nevada City, California, a vein has been worked for more than two thousand feet in schists to a point where it obliquely enters a diabase dike. On entering the dike the vein immediately splits into several branches. Can you explain the splitting of the vein?

16. Why is serpentine difficult to mine in?

17. Why does quartz usually make a safe roof in a mine stope?

18. What kind of jointing is most dangerous in crosscuts?

19. In what combinations is sulphur relatively innocuous as an impurity in coal?

20. Descending mine waters are usually acid but become alkaline with depth. Explain the reason for the change. How does the change affect ore deposition?

21. At certain stages, while the Simplon tunnel was being driven between Brigue, in Switzerland, and Iselle, in Italy, a distance of 12.4 miles, why was it necessary to spray the headings with cold water? Explain in full.

22. In July, 1908, while the Loetschberg tunnel was being driven through the Bernese Alps in Switzerland, the heading which had been extended in solid rock for 1.6 miles from the north portal broke into water-soaked grounds. Sands and muds, which quickly rushed in, filled 5900 feet of the tunnel and killed twenty-five men. It proved necessary to abandon the original line and select a new one for this portion of the tunnel. What were the geological conditions which attended this catastrophe?

23. The Paleozoic beds in central New York dip gently to the south. The coal-bearing beds in Pennsylvania are the youngest Paleozoic formations. It is stated that more money has been expended in New York State prospecting for coal than would have paid for a state survey. How would a knowledge of the geological structure have saved the expense?

CHAPTER VI

AGRICULTURE

1. Why do stones "grow" out of the ground? Describe the processes by which this emergence takes place. How is the knowledge of this process important in the laying of foundations?

2. What economic advantage may be taken of the sediment in rivers?

3. Though the interior of Labrador has a quarter of its surface covered with lakes, there is a low-lying belt one hundred miles wide nearly devoid of lakes on its westward side towards James Bay. This is due to the marine clays and sands which reach inland to a height of four hundred feet above the sea. (Coleman, America). How are these sands and clays responsible for the absence of lakes?

4. If a lake which was in existence for a thousand years has been drained and a sufficient length of time has elapsed to permit vegetation to cover its bottom, what proofs would be afforded of the former existence of the lake? What would be its value for agriculture?

5. Why are the alluvial plains bordering the mountains of desert regions much more extensive than those in moist regions?

6. Which side of a mountain of homogenous structure is most likely to have a gentle slope? Why? Where will the land be more suitable for agriculture?

7. Does the absence of soil in any given place mean that weathering is not in progress there?

8. A promoter of an irrigation scheme for Western Canada built a ditch through a plain underlain by loess. It would not hold water until lined with concrete. Could this have been foreseen after a geological examination?

9. A pond is sometimes found above the water-table of a region as in figure 11. Explain. How can the explanation be tested? How could this pond be drained?

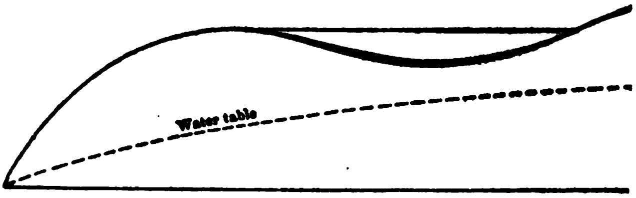

FIG. 11—AFTER U. S. GEOLOGICAL SURVEY

10. How might one seek to determine whether alluvial land within a meander curve had formed by accretion to the bank or as an island that was later tied to the shore by the filling up of the channel back of it? Ownership of such land often depends on the mode of formation.

11. A fertile farm lay on the flood-plain of the Mississippi River. A steep bank permitting direct shipping by the river steamers was regarded as a further attractive feature. One year the farm was destroyed. On what part of the meander curve was the farm? What was the cause of the loss?

12. Is the soil least subject to wash on slopes of equal steepness in New England or in the southern Appalachians? Which can be more readily plowed? Which is the more necessary to leave forested?

13. By what changes in a river may a formerly fertile flood-plain become useless for agriculture?

14. Would more fertile soil be expected on the north or the south sides of the high mountains in the southern Appalachians?

15. Why are flood-plains generally fertile? Under what conditions are infertile flood-plains formed?

16. The "Clay Belt" of Northern Ontario and Northwestern Quebec is formed by a thick veneer of clays and sands on the Archean rocks. The clay belt area is for the most part level and fertile and is in striking contrast to the bordering lands with their thin soils and large areas of exposed rocks. What explanation can you offer for the origin of the "clay belt" and what proofs are required to substantiate your theory?

17. In the glaciated region of Western New York a reclaimed marsh showed the following section:

Soil	3 feet
Moss litter	2 feet
Peat	3 feet
Shell marl	2 feet
Gravel	3 feet
Bed rock	

With the aid of the above section give the history of the marsh.

18. Contrast the soils of humid regions with those of deserts.

19. Why are the soils of deserts relatively rich in plant food?

20. What normal constituents of the soil of humid regions are lacking in deserts?

21. The sedimentary soils of the foothills of the Sierra Nevadas are red; the soils of the valley derived from these foothills are not red. Explain.

22. The gases contained in the pore space of soils in humid regions contain much carbonic acid. What is the source of this reagent? What is its function in the formation of soil?

23. To what extent is the aridity of a region measurable in inches of rainfall? To what extent is aridity due to the humidity of the air between rains?

24. Why do some irrigated lands in California, Nevada, and Utah have to be drained?

25. Under what conditions is artificial drainage of soil unnecessary?

26. Under what conditions is gypsum beneficial to an alkaline soil?

27. What are adobe soils? What difficulties to cultivation do they present?

28. In otherwise good soils of arid or semi-arid regions alkali salts accumulate in certain areas and render the soil worthless. Explain the process and the cure for the evil.

29. What is the source of the clay constituent of soils?

30. Why do the cultivated soils of the Piedmont regions of the Southern States wash down the slopes so that the hills tend to become denuded?

31. What is the mechanism of creep? How does creep on hillsides affect soils?

32. What is loess? What kind of soil does it form?

33. What is the source of phosphates in soils? Of potash?

34. How may moisture in soils be retained in the dry season in the absence of irrigation?

35. How has hydraulic mining in California affected farming in the Sacramento Valley?

36. What is the relation between the snowfall in the Sierra Nevada mountains and farming in the Great Valley of California?

37. What characteristics of soil determine the amount of water required for irrigation?

38. What is laterite? Under what conditions does it form?

CHAPTER VII

HYDRAULIC ENGINEERING

1. A dam in Pennsylvania was built on rock which consisted mainly of sandstone beds from one to three feet thick which dipped (inclined) down stream; between these beds were some shaly layers two to four inches thick. The rocks were somewhat jointed and water was able to percolate to the various beds. Account for the breaking of the dam with the resultant great loss of property.

2. More than fifty dams in the United States have gone out in the past few years. How would a knowledge of geology have enabled the builders, in many cases, to make them stable?

3. The Johnson City, Tenn., reservoir was located and constructed without a study of the geological conditions. When the reservoir was filled the water escaped through a clay-filled cavern and ran out into a railroad cut. The accompanying diagram (Figure 12) illustrates the conditions. Explain why a geological study of the region would have prevented this.

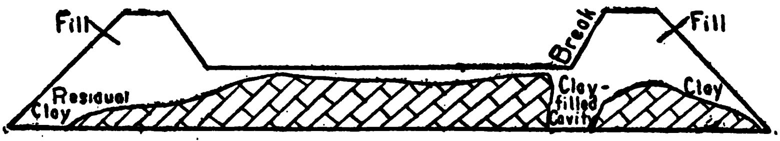

FIG. 12

4. In a region such as is shown in the diagram (Figure 13) where will waterfalls be formed? Are they of common occurrence? In this region how will the width of the valleys vary in different parts?

5. Why should glacial drift be tested before a dam is constructed on it?

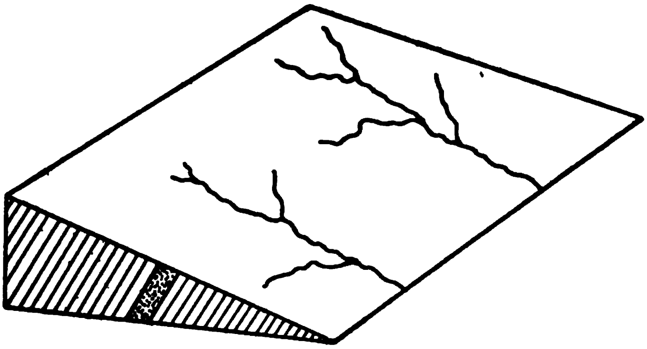

FIG. 13

6. Would there be any relation between a great forest fire on the headwaters of the Missouri and a subsequent flood in the lower Mississippi? Explain.

7. How does the presence or absence of sediment in a river affect its storage for power and for irrigation?

8. Why did the Canadian Government protest when it was proposed to allow some of the water of Lake Michigan to flow through the Chicago drainage canal into the Mississippi?

9. If the Canadian Falls continue cutting back what effect will this have on the American Falls?

10. How would you estimate the quantity of water available for irrigation in the gravels of Livermore Valley, California?

11. In the Coast Ranges the percentage of run-off varies somewhat with the distribution of the rains in time. What is the reason for this?

12. If Lake Tahoe, California and Nevada, were to be tapped by a tunnel for the purpose of utilizing its waters, how would the amount of water available compare with that now available in the Truckee river?

13. If the outlet of Lake Tahoe were to be dammed so as to raise the level of the lake, say, one hundred feet, how would the dam affect the quantity of water available?

14. It has been proposed to dam the canyons of certain north-flowing tributaries of the Little Colorado. The walls of the canyons are steep and are composed of very porous sandstone. What is the risk of losing water by leakage into the sandstone if dams were built?

15. The Crystal Springs dam, California, though very close to the San Andreas fault was not even cracked at the time of the earthquake in 1906. What is the lesson?

CHAPTER VIII

SANITARY ENGINEERING

1. A city situated on limestone obtained its water from a central well and disposed of its sewerage in shallow pits. What was the probable origin of an epidemic of typhoid that caused the death of many of its inhabitants?

2. In Minneapolis, St. Paul, and other places in Minnesota, cellars and even ponds have been drained by wells. State the conditions which made it possible for ponds to exist in these regions, and how they were drained by wells. What conclusions are drawn as to the advisability of using large springs in such regions as a source of water supply?

3. What is the common origin of lakes in regions of thick limestone? What is their size? Have they any economic importance? Examples.

4. Explain with the aid of diagrams the importance of knowing the direction of the prevailing coast-wise currents with reference to fixing with safety the relative positions of water supply intake and sewage outlets in the case of cities located on the Great Lakes.

5. Which, in general, will be the safer to drink, water that has flowed through limestone or that which has percolated through sands and gravel?

CHAPTER IX

RECLAMATION

1. Why is alkali so prevalent in the soils of arid regions? What is the effect of gypsum on alkaline soils? What salts render soils alkaline?

2. Lands may be reclaimed (1) by supplying water for irrigation, (2) by draining excess water, (3) by diking off water from low land, (4) by filling flooded depressions, (5) by amelioration of worthless soil. Cite instances of these methods and compare the general character of the soils thus rendered available for use.

3. The marsh lands of the Sacramento Valley are gradually being reclaimed by diking them off from the river. What will be the effect of this reclamation on the river?

4. In the valley of the Nile the land is enriched by deposition of silt by annual inundations. In California similar inundations induced by hydraulic mining ruined the farm lands. Why the difference in result?

5. What was the effect of hydraulic mining in California on the stream trenches in the valleys? How have these trenches been affected by the stoppage of hydraulic mining?

6. What is the relation of alkalinity to rainfall? To drainage?

7. In the Great Valley of California some lands which lie below sea level are shut off from the river water by dikes and successfully cultivated. What is the character of the subsoil?

8. In a marsh of the Great Valley of California the skeleton of a whale was found a few years ago. Are the deposits in the marshes marine?

9. How is the drainage of the Tulare basin, California, affected by the delta of the Kings River?

10. The smaller streams of California in summer are often dry in the day time but flow at night. Why is this?

CHAPTER X

OIL GEOLOGY

1. The San Juan oil field of Utah is believed to have been drained by the San Juan River that cut a canyon through the anticline. Construct a diagram to show the essential structural features of the region and the conditions favorable for the accumulation of oil. Then show how erosion by the San Juan River drained the field.

2. How do you explain the alternation of the oil-bearing and water-bearing strata in an oil well?

3. What structural features of sedimentary strata favor the accumulation of oil?

4. Why does salt water appear in an oil well as it approaches exhaustion? Origin of the salt water?

5. Asphalt occurs in some of the rocks in a region where, it was hoped, oil would be found in paying quantities, showing that some strata or stratum had contained oil. A careful examination of the overlying rocks seems to show that none of them is impervious. If these observations are correct what will be the future of the field? Why?

6. If irregular oil sands occur as shown in figure 14, indicate where, if at all, oil, gas, and water occur.

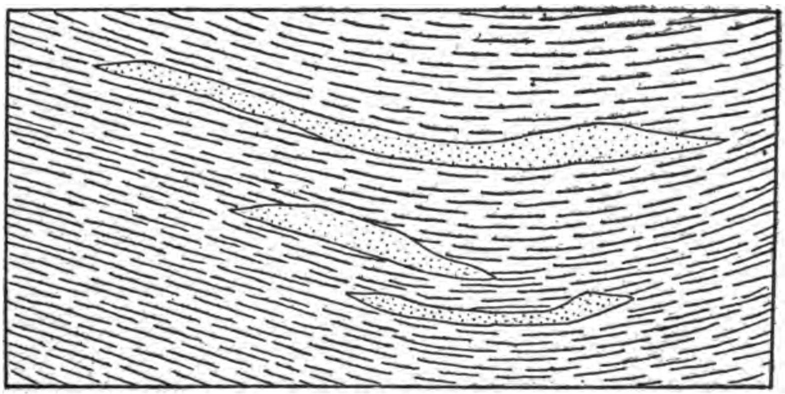

FIG. 14

7. Assume that the following geological map (Figure 15) was made by an oil geologist. If sand known to be oil-bearing in another part of the region underlies the oldest stratum shown on the surface where would you advise that a well be drilled for oil? for gas? Construct a section along the line A-B.

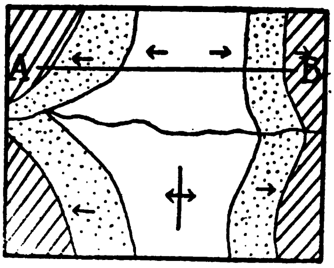

Fig. 15

CHAPTER XI

MILITARY ENGINEERING

1. Indicate on the side of the block diagram (Figure 16) the probable structure of the "Paris Basin." What was the military importance of the ridges in the Great European War?

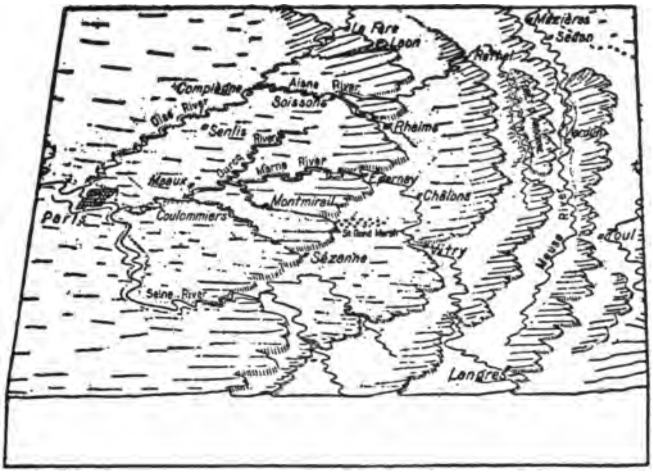

FIG. 16—AFTER D. W. JOHNSON

2. When the Athenians laid siege to Syracuse on the island of Sicily they found it naturally defended by a limestone cliff which was unscalable except for individuals. In one place, however, there was a defile through the perpendicular cliff with a gradual slope where an attacking party could easily mount. The rock underlying this passage is igneous. Explain how the passage was formed.

3. The Italians were unable to drive the Austrians from the Carso Plateau, a typical Karst region, during the Great War. What natural conditions made this region especially easy to defend?

4. On the Belgian front during the Great War the English geologists found that in one sector the water-table fluctuated one hundred or more feet during the year and they planned their mines with this in mind. The Germans, who did not make a geological study of the sector did not take this into

account. How was this knowledge utilized by the English and why was it necessary for the Germans to abandon many of the tunnels they had so painstakingly excavated? How did the English obtain their knowledge of the underground water?

5. In portions of Canada where the bed rocks are unusually hard, the surface was scoured and planed into moutonee forms by the ice sheet. How can one on a cloudy day without the aid of a compass, determine directions for travel by the help of these forms and the glacial grooves and striae? (Coleman, America.)

6. What is the origin of the ridge of the Chemin des Dames (Figure 17) and of the isolated hill upon which Laon is situated?

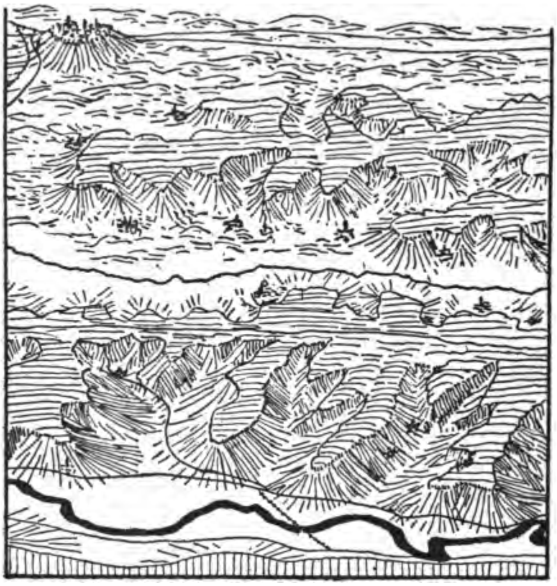

FIG. 17—MODIFIED AFTER W. M. DAVIS

PART II

QUESTIONS ARRANGED ACCORDING TO GEOLOGICAL TOPICS

CHAPTER XII

QUESTIONS ON WEATHERING

1. Why are rocks which have many joints and bedding planes more likely to be strongly affected by the weather than those which have fewer? Is this equally true in arid and moist, and warm and cold regions?

2. In clay pits, it is frequently seen that the clay in the upper part is yellowish, while that in the lower part is blue-gray. Why is this? Give a definite answer.

3. Adobe is a fine, clayey material, which, in the form of sun-dried brick, is an important building material in the arid regions of the United States and Mexico and when irrigated forms productive soil. It accumulated on plains and is ascribed to wind action and wash. Trace its history back to the rock from which it was derived, and tell how it was formed.

4. A large area of land composed of granite is situated in a warm, moist climate and has been subjected to prolonged weathering and erosion. (1) State in what way each of the mineral constituents of the rock was affected and what products resulted. (2) What sedimentary deposits were formed in the seas into which the streams of the region flowed, and from what was each derived? (3) After these sediments had accumulated to a great thickness they were subjected to great lateral pressure. State into what metamorphic rocks they were changed.

5. Why is the sand beneath a swamp generally very white?

6. Vertical sections in red clay soils of the South show a white clay area about old, rotten tree stumps. Why?

7. In New York and other cities of the eastern United States many buildings are faced with a red sandstone, the blocks of which are laid on edge, i. e., the bedding planes are

vertical. An examination of these stones often shows that the "face" has split off in leaves, producing an unsightly surface which necesstates either new blocks of stone or redressing. Tombstones of this same material are similarly affected, the broad sides often being split off in leaves, obliterating the inscriptions. Explain.

8. Why is granite or concrete preferred for curbstones to laminated rocks such as laminated limestone?

9. It has often been noticed that stones quarried in the autumn are more likely to disintegrate than those that were quarried early in the summer. Why is this?

10. Which side of a mountain of homogenous structure is most likely to have a gentle slope? Why? Cite examples.

11. What would have been the effect of the weather on the Egyptian obelisk, now in Central Park, New York City, if it had been erected in southern California instead?

12. If the climate of the Mohave desert of California should become moist, what agents of disintegration would become weaker and what ones more effective?

13. Does the absence of soil in any given place mean that weathering is not in progress there?

14. Would a stone wall stand longer in the Province of Quebec than in the State of Mississippi? What are the principal agents of weathering by which it would ultimately be destroyed in each place?

15. It is stated that Somerset House in London and York Minster both of which are built of limestone, are much more decayed on the south than on the north sides. Explain.

16. The course of a stream which has so undercut its banks as to form a cliff such as that shown in figure 18 was so changed that it now flows on the opposite side of its valley.

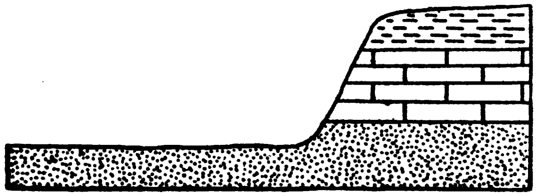

FIG. 18

Make a series of drawings showing the profiles of the cliff which will, in time, be produced as a result of weathering.

17. Why are steep slopes characteristic of many arid regions?

18. Before Hilgard Hall was built on the Campus of the University of California the proposed granite was examined in the quarry by a geologist and approved by him. What are the common defects of granite which detract from its value as a building stone?

19. In humid regions the slopes of the hills become lower with the progress of time; in the desert they remain steep. What is the reason for this?

CHAPTER XIII

QUESTIONS ON WIND WORK

1. Why are the bottoms of telegraph poles in parts of Arizona protected by cement or in other ways?

2. In the Bermuda Islands the rock is composed of wind-blown shell-sand and is much cross-bedded. How was the irregular structure produced? Draw a section to show this structure.

3. Adobe is a fine, clayey material, which, in the form of sundried brick, is an important building material in the arid regions of the United States and Mexico and when irrigated forms productive soil. It accumulates in basins and is ascribed to wind action and wash. Trace its history back to the rock from which it was derived, showing how it was formed.

4. Construct diagrams showing successive positions of a migrating sand dune.

5. Why are the surfaces of some desert rocks smooth while others are much pitted? Are rocks with such surfaces found in moist regions? How are the pits formed?

6. What are the characteristics of wind-made depressions?

7. Is a deposit rich in undecomposed mineral grains indicative of a dry or moist climate? Give your reasons.

8. Origin of loess. Observe automobiles traveling on a country road. At what season is the most dust raised? How high does it rise? How long is it suspended? To what distance and in what direction can dust be noted on the vegetation? What is the effect on vegetation in the course of years? Compare with wind action on a river flood-plain composed of fine silt in which the flood water period is from May to September.

9. What limit is there to the depth to which a region can be deepened by wind work?

10. Enumerate the various ways in which sand may begin to form dunes.

11. In deserts a mound of sand marks the presence of some springs. How was the mound formed?

CHAPTER XIV

QUESTIONS ON GROUND WATER

1. In Tennessee, sink holes occur in belts roughly parallel to each other. What inference can be drawn as to the character and position of the rocks? Construct a diagram to illustrate your explanation.

2. In a limestone region a river flows in a narrow, rock-bound valley one hundred feet deep. This is within an older valley with flats and gently sloping sides rising to a level upland two hundred feet above the stream. Are caves likely to be found? Where, why, and at what elevation? On an upland farm would you have to dig deeper to obtain water where the rock formation is limestone or where it is shale?

3. In the Great War the Italians had great difficulty in driving the Austrians from the Carso Plateau, a typical Karst region. Show how the topography especially favored the Austrians.

4. The Johnson City, Tenn., reservoir was located and constructed without a study of the geological conditions. When the reservoir was filled the water escaped through a clay-filled cavern and ran out into a railroad cut. Diagram 12, page 33, illustrates the conditions. Explain why a geological study of the region would have prevented this.

5. Why do some caves have passages at several different levels?

6. Why are the roofs of some caves entirely free from stalactites?

7. Are caves more likely to be developed in limestone regions with steep dips (inclinations) or in those which are more nearly level? Give reasons for your answer.

8. Why are the stalactites of some caves cylindrical, while others are broad and sheet-like? How can you test your explanations?

9. Why can not extensive caverns be formed below the level of the largest valley of a region?

10. Explain the presence of holes in stalactites.

11. Under what conditions may sink holes become the sites of lakes? In Florida such lakes sometimes disappear. What means can be taken to restore them?

12. A city situated on limestone obtained its water from a central well and disposed of its sewerage in shallow pits. What was the probable origin of an epidemic of typhoid fever that caused the death of many of its inhabitants? Construct a diagram to illustrate your conclusions.

13. State fully the origin of so-called "petrified moss".

14. In a region such as that shown in figure 9, page 18, where is a spring likely to occur? Under what conditions may a spring flow on the opposite side of the hill?

15. On figure 4, page 14, indicate the position of the water-table in a homogeneous rock (1) after a wet season and (2) after a dry one.

16. Account for the fact that at Colonial Beach, Va., the sinking of one well on the water front has stopped the flow of a neighboring well a few feet higher.

17. In a region in which the rocks have the relation shown in the diagram (Figure 3, page 14,) where should wells be sunk? Would any be flowing wells? If so, where?

18. Poland Springs, Maine, are situated near the top of a hill and the spring which supplies Wilmington, Vt., with water is near the top of Haystack Mountain. What is the probable source of the water in each?

19. In some places a pond is found above the water-table of a region as in figure 11, page 30. How may this be explained?

20. At Minneapolis, St. Paul, and other places in Minnesota, cellars have been drained by wells. Explain. What conclusions can be drawn as to the advisability of using large springs in such regions as a source of water supply?

21. Account for the fact that some fresh artesian water is obtained on sand reefs separated from the mainland by salt water. Draw a diagram and explain.

22. At Denver, Col., some four hundred wells were sunk in an area forty by five miles and an abundance of flowing water was obtained. Account for the fact that in about fifteen years many of the wells ceased to flow.

23. A dam in Pennsylvania was built on rock which consisted mainly of sandstone beds from one to three feet thick which dipped (inclined) down stream; between these beds were some shaly layers two to four inches thick. The rocks were somewhat jointed and water was able to percolate to the various beds. Account for the breaking of the dam with the resultant great loss of property.

24. A hotel on a Swiss lake is situated as shown in figure 19. Why do geologists avoid it? How was this condition brought about?

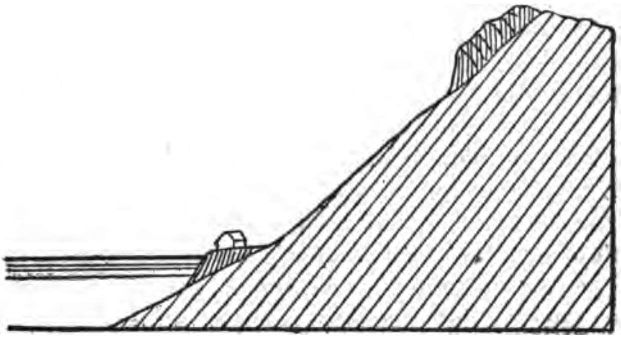

FIG. 19—AFTER W. M. DAVIS

25. Figure 2, page 11, is a cross-section of Culebra Cut of the Panama Canal showing the surface before and after one of the slides. Give the cause of the slide. When will the sliding cease?

26. Landslides were so reducing the lawn at Mount Vernon that the broad lawn in front of the house and the foundations of the house were in danger. A study of the strata of which the bluff is composed showed that one bed of sandstone, in particular, contained so much water that it kept the adjacent beds wet. Why was a drainage tunnel driven back from the river into this sandstone bed and what results could be expected?

27. Houses with shallow foundations built on hillsides are frequently cracked as the result of "hillside creep." What is this and how can it be prevented?

28. More than fifty dams in the United States have gone out in the past few years. How would a knowledge of geology have enabled the builders, in many cases, to make them stable?

29. A railroad train in Brazil was wrecked by a landslide where the dip of the rock is that shown in diagram, figure 10, page 21. Why did the slide occur?

30. London, England, is underlain from the surface downward, first by porous materials, second by the impervious "London Clay", and this in turn, by other wet strata. One underground railroad was dug near the surface and another in the "London Clay." Which "subway" is the drier and more healthful? Explain.

31. Landslides frequently occur in the hills of the Coast Ranges. What is the relation of this frequency to the stage of geomorphic development?

32. What physiographic and geologic conditions are favorable to the formation of lakes by landslides? What may be the extent of such lakes and what is their economic importance?

33. The water-table in certain localities in California fluctuates several feet between summer and winter. How does this concern an architect about to build a house with a deep basement?

34. In limestone regions the relation of rock to soil is shown in figure 20. Why does not the soil grade into the rock as it does where granite is weathered?

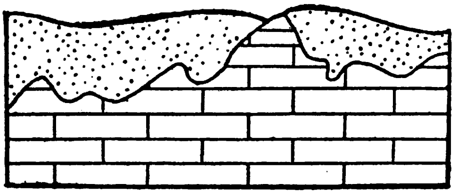

FIG. 20

35. Study a specimen of polished agate. What proof is offered of the origin of the layers?

36. A farmer in a region underlain by granite wrote to the Director of a State Geologic Survey asking if artesian water

could be obtained by drilling a well one thousand feet deep. What answer should be given and why?

37. Under what conditions may wells drilled in limestone regions be used in draining lands or in carrying away surplus accumulations of surface water, or in preventing lakes from rising above a definite level?

38. What are the underground conditions that permit a drilled well to be used either as the source of water supply for irrigation or as a drainage well, depending on which is required?

CHAPTER XV

QUESTIONS ON STREAMS, STREAM EROSION, AND STREAM DEPOSITION

1. Why is Niagara River unable to remove the algae over which it flows at the falls? How could you test your answer?

2. Why are the streams of New England, as a rule, seldom muddy; and why are those in the Southern Appalachians generally yellow?

3. The following is a section (Figure 21) of the Grand Canyon of the Colorado. Show the position of the hard and soft rocks or beds, especially in the development of platforms and cliffs.

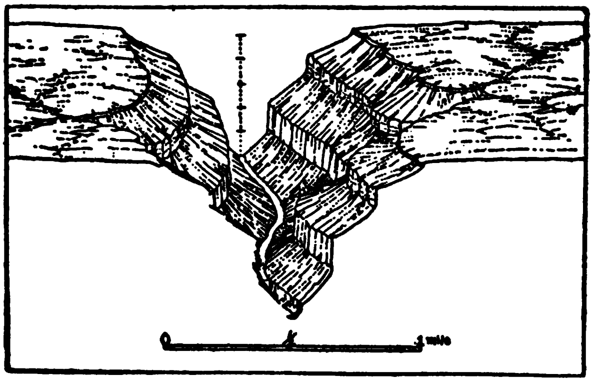

Fig. 21—Modified After W. M. Davis

4. Mention a number of ways by which mountain passes have been formed.

5. When is agriculture most favored, during the youth of a region, during its maturity, or during its old age? During what stage is railroad building the most difficult? Why then, are railroads built into regions that are in this stage of the erosion cycle?

6. Can you judge from the drainage shown in the accompanying map (Figure 22) what is the structure of the under-

lying rocks? Construct an East-West section to show the geological structure. What principles guide your answer? In what portions of the United States is such drainage developed, and why?

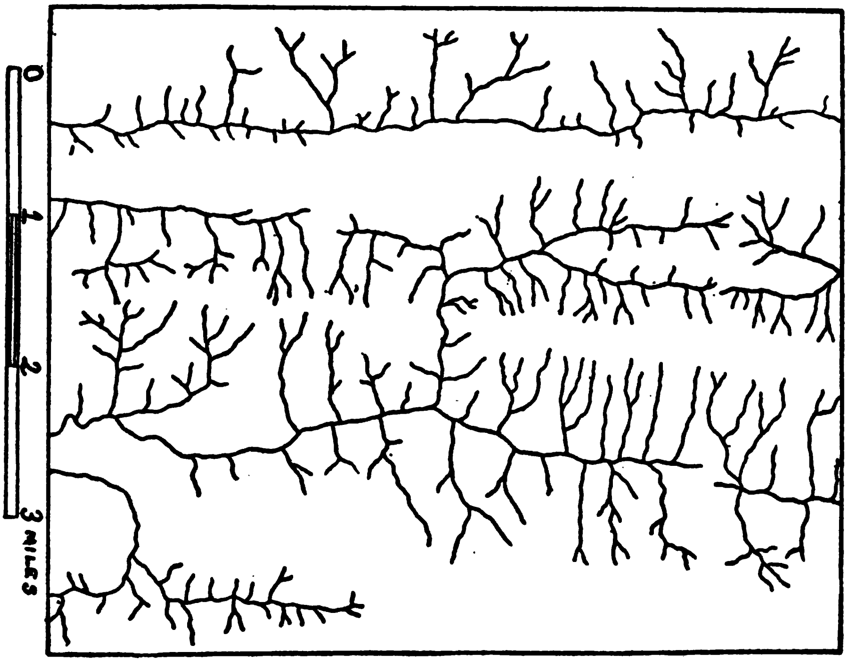

FIG. 22

7. A stream is bordered by alluvial terraces as is shown in figure 23. Indicate on the figure the conditions which probably determine the position of the terraces.

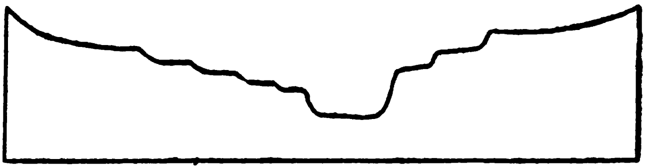

FIG. 23

8. The marsh lands of the Sacramento Valley are being gradually reclaimed by diking them off from the river. What will be the effect of this reclamation on the river?

9. In a region such as is shown in figure 13, page 34, where will waterfalls be formed? How will the width of the valleys vary in different parts? Where is a wind gap likely to be formed, and where is stream piracy likely to occur? If you can not redraw, cut out the diagram, paste it on your paper and indicate in pencil.

10. If a small stream flows in a somewhat winding course through a valley composed of silt (Figure 24,) what meanders will develop in the course of time? Draw.

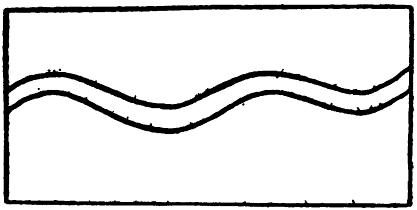

FIG. 24

11. Why were geologists justified in opposing the recommendation that $50,000,000 be expended in dredging a channel for ocean-going vessels from Albany to New York City?

12. More than one hundred years ago a family of eleven brothers of good Anglo-Saxon stock migrated from North Carolina to Kentucky. Ten of them settled in the mature region of Kentucky and one in the gentle, rolling, fertile, "blue grass" country. What has probably been the effect of these different environments upon the descendants of those men?

13. In what portion of the erosion cycle is the region described below? "It is what the mountaineers themselves call a rough country. The steep hills rise from 700 to 1200 feet above their valleys. The valleys are nothing more than gorges. Level land there is none and roads there are almost none. Valley and road and mountain stream coincide. In summer the dry or half-dry beds of the streams serve as highways; in the winter when the torrents are pouring a full tide down in the hollows, foot-trails cut through the dense forest that mantles the slopes are the only means of communication. Then intercourse is practically cut off. Even in the best season transportation is in the main limited to what a horse can carry

on its back besides its rider. In a trip of 350 miles through the mountains we met only one wheeled vehicle and a few trucks hauling railroad ties, which were being gotten out of the forests. Our camp wagons, though carrying only light loads had to double their teams in climbing the ridges. All that had been done in most cases to make the road over a mountain was to clear an avenue through the dense growth of timber so that it proved, as a rule, to be just short of 'impassable.' " (Semple).

14. It is stated that by natural causes hundreds of pioneers and travellers in Arizona, New Mexico, and Texas have lost their lives by camping in the attractive-looking, grassy flats located on the bottoms of dry creeks. Explain. In your answer take careful note of the climatic conditions of these regions. In such a region is erosion rapid or slow? Why?

15. The rivers of the Sierra Nevada mountains are consequent; those of the Coast Ranges are subsequent. Which is the older geomorphy?

16. What was the effect of hydraulic mining in California on the stream trenches in the valley? How have these trenches been affected by the stoppage of hydraulic mining?

17. During what stage of an erosion cycle is the water-table lowest? When is the run-off greatest?

18. A commission appointed by the city of Pittsburgh recommended the building of seventeen reservoirs in the upper courses of the Allegheny and Monongahela Rivers, at an expense of $20,000,000, in order to reduce the floods to which that city is subject. Was the recommendation a good one? What influence would such reservoirs have upon the level of the river in times of drought?

19. In what stage of erosion is the region in which you live? Has there been more than one cycle? Proof.

20. The accompanying figure (Figure 25) is a diagram of the right bank of the Rhine between Bingen and Coblentz. Without knowing the structure of the region what explanation can be suggested to account for the level surface and valleys of different depths? Draw sections showing this region as it was in an earlier and as it will be in a later cycle of erosion.

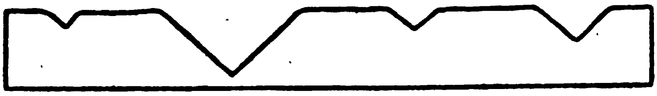

FIG. 25

21. How many cycles of erosion are shown in the following diagram? (Figure 26). Redraw and indicate on your figure.

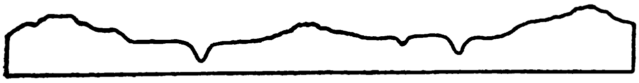

FIG. 26

22. Why are the bottoms of broad channels of a river generally covered with fine sediment while those of narrow channels are sometimes found to be covered with coarse gravel?

23. Construct a cross-section of a valley filled by stream deposits and show in it the arrangement of the coarse and fine sediments.

24. During the season of spring floods which rivers will be the more turbid, those flowing from a glaciated region or those from an unglaciated region of similar rock formations and relief? Why?

25. Make a longitudinal section of the delta made by a torrential stream flowing into a lake.

26. What becomes of the drainage of the San Jacinto mountains in California?

27. In canoeing on a river such as that shown in figure 1, page 9, what course must one take? Draw cross-sections along A-A, B-B, and C-C, to show the probable configuration of the banks and the river channel.

28. Under what conditions may a fall retreat, remain stationary, advance, and disappear?

29. Why is there four times as much mineral matter in solution, on the average, in the rivers of the semi-arid portions of California as in the rivers of moist regions?

30. Where is the estuary of the Sacramento River? How was it formed? Study maps.

31. The Salinas River, California, in its lower stretch is for some miles parallel to the shore of Monterey Bay before it escapes to the sea. Why does it take this course? See topographic map.

32. Why does the south drainage of the San Bernadino Mountains hug the base of the San Jacinto Mountains?

33. If the Colorado River were to be diverted to the Salton Basin what would be the effect upon the river immediately above Yuma?

34. What is the difference in the slope of the delta of the Colorado River toward Salton Sea and toward the Gulf? What is the reason for this difference?

35. The Fraser River flows in a gorge through a great mountain ridge from an open, lower country to the East. Explain the origin of the gorge. Study maps.

CHAPTER XVI

QUESTIONS ON GLACIERS

1. If a glacial boulder has approximately the shape shown in figure 27 what will probably be the direction of the scratches?

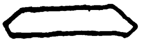

FIG. 27

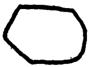

FIG. 28

2. If it has the shape shown in figure 28, what will probably be the direction of the scratches? Why?

3. What was the direction of the motion of the glacier which excavated the basin shown in the accompanying cross-section?

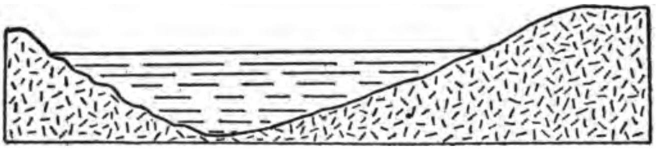

FIG. 29

4. What determines the size of a valley glacier?

5. What are the limits to the heights of ice pillars? Are they the same in all latitudes? altitudes?

6. How can one determine approximately the thickness of the glacier that once occupied the Yosemite Valley? (See Plate 31, U. S. Professional Paper 60.) How thick was the ice?

7. Compare and contrast typical topography due to glaciation with that due to stream erosion. Construct a drawing to show this difference. The regions shown on the St. Paul, Minn., and Charleston, West Virginia, topographic sheets are typical, although the regions are not in the same stage of erosion.

8. How can dune topography be distinguished from morainic? Wherein may the two be similar in appearance? Why?

9. Upon the disappearance of a mountain glacier from a valley, what proofs of the former existence of the glaciers are afforded by a study of the tributary valleys?

10. Draw a cross-section of a mountain glacier to show why the summits of some medial moraines are fifty feet or more above the general surface level of the ice.

11. Trace the possible course of an angular rock fragment from the time it falls from a cliff to the surface of a mountain glacier until it is deposited in the terminal moraine.

12. Trace the possible courses of a piece of rock plucked from its bed by a glacier until it is deposited in the terminal moraine.

13. If the slope of the bed of a glacier is as indicated in figure 30 what will be the character of the surface of the ice? Draw.

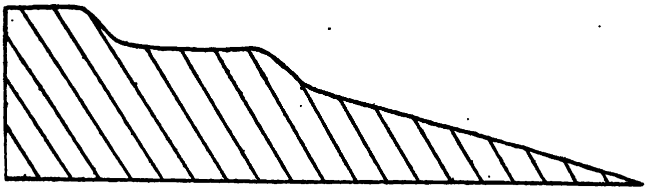

Fig. 30

14. In portions of Canada where the bed rocks are unusually hard, the surface was scoured and planed into moutonee forms by the ice sheet. How can one on a cloudy day without the aid of a compass determine directions for travel by the help of these forms and the glacial grooves and striae?

15. The most extensive lake region in the world, one similar to those of Scotland, Finland, and Scandinavia, but on an immensely larger scale occurs on the Archaean Shield of Canada, that great mass of crystalline rocks about Hudson Bay. State all of the elements in the production of this condition.

16. Canoe routes can be followed in almost any direction for hundreds of miles across the "rocky lake" type of country so prevalent on the Archaean Shield of Canada. A canoe may be launched on the north shore of Lake Huron or Superior, or from some little railroad station beyond Lake Superior, and worked north and west to Hudson Bay or Lake Winnipeg, with few portages of more than a mile or two, often for many miles with nothing more than a "drop over"

from one water level to another. State the factors which brought these conditions about.

17. The valley of the Schroon River in the Adirondack province of New York, is bordered and in places filled, to a width of a half-mile or more with stratified sand and gravel. These deposits are of approximately equal altitude. From this evidence what would you conclude was the origin of the sand flats? What is the origin of Schroon, Paradox, and Brant Lakes? (W. J. Miller, the Adirondack Mountains, New York Mus. Bull. 193, page 67.)

18. Why should glacial till be tested before a dam is constructed on it?

19. A railroad in Alaska has been built across 5 1-2 miles of the Allen Glacier. What future difficulties may be expected?

20. What two agencies may be responsible for perched boulders? Why are perched boulders not in their most stable positions? Explain in full.

21. Show how cirques will in time be obliterated.

22. How were such peaks as the Matterhorn formed?

23. Give the history of a valley having the cross-section shown in figure 31.

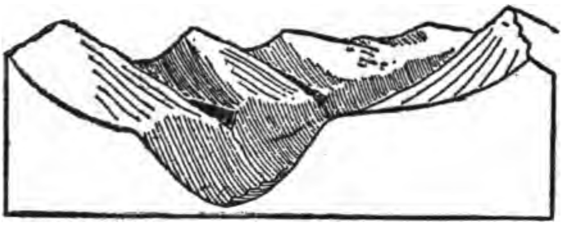

Fig. 31

24. Why are stone fences more abundant in Massachusetts than in Georgia? Why more abundant than in Illinois?

CHAPTER XVII

QUESTIONS ON OCEANS

1. Contrast the two sides of San Francisco Bay. Explain the differences in the shore contour. Study topographic maps.

2. What is the origin of the deep trough in Monterey Bay, California? Consult map.

3. How were the features shown in figure 32 produced? Name c-d, c-b, and g. Is this coast old or young? Where are similar coasts?

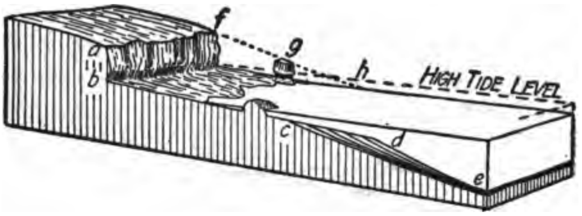

FIG. 32—FROM LAHEE'S FIELD GEOLOGY, McGRAW-HILL, NEW YORK

4. What is the origin of Burlington Bay, Lake Ontario? Consult map.

5. On the east side of Tomales Bay, California, there are terraces and marine deposits with abundant shells at elevations of twenty or thirty feet above sea level. On the west side there are neither terraces nor marine deposits. Explain the contrast.

6. Explain the origin of San Francisco Bay, California. Explain the differences in the shore contours.

7. Draw a section through the delta of Alameda Creek, San Francisco Bay.

8. What is the origin of the harbor at Vancouver, B. C.?

CHAPTER XVIII

QUESTIONS ON STRUCTURE

1. Many passes in the Southern Appalachians have been formed as indicated in figure 33. Construct diagrams to show how this topography was developed.

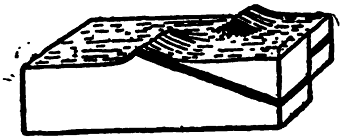

FIG. 33—FROM LAHEE'S FIELD GEOLOGY, COPYRIGHT MCGRAW-HILL, NEW YORK

2. What is the origin of the breccia shown in figure 34 and what may be the economic importance of such structures? Why are not all rocks brecciated by similar forces?

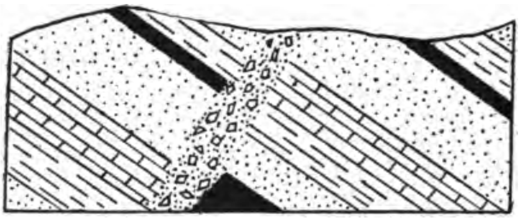

FIG. 34

3. The dip and strike of the beds of certain regions are as shown in figure 35. Construct sections to show the structure.

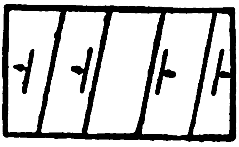

FIG. 35

4. What kind of faults are shown in figure 36 A and B? Do both diagrams show the correct dip of the fault plane?

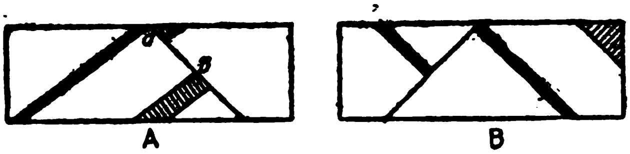

FIG. 36—FROM LAHEE'S FIELD GEOLOGY—COPYRIGHT MCGRAW-HILL, NEW YORK

5. Construct a diagram to show what would have been the surface of the region illustrated in figure 37 had not erosion reduced the land.

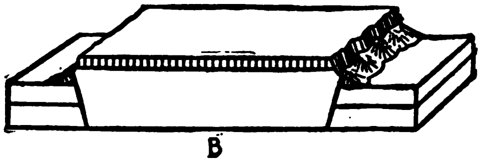

FIG. 37—FROM LAHEE'S FIELD GEOLOGY—COPYRIGHT MCGRAW-HILL, NEW YORK

6. Which of the faults shown in figure 38 is the older?

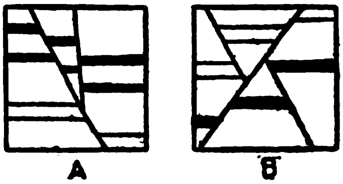

FIG. 38—FROM LAHEE'S FIELD GEOLOGY—COPYRIGHT MCGRAW-HILL, NEW YORK

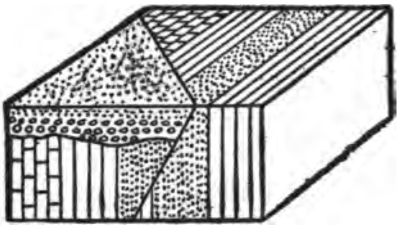

FIG. 39—FROM LAHEE'S FIELD GEOLOGY—COPYRIGHT MCGRAW-HILL, NEW YORK

7. Explain the abrupt termination of the strata on the right and the presence of horizontal sediments on the act land their absence on the right in figure 39. Give the geological history of the region.

8. Compare and contrast the size of grain (texture) of the rock of a thin and of a very thick dike. How does the texture of the rock near the surface of a massive flow differ from that deeper down? What is the direction of the jointing?

9. What is the relative age of the dike and sedimentary beds in figure 40?

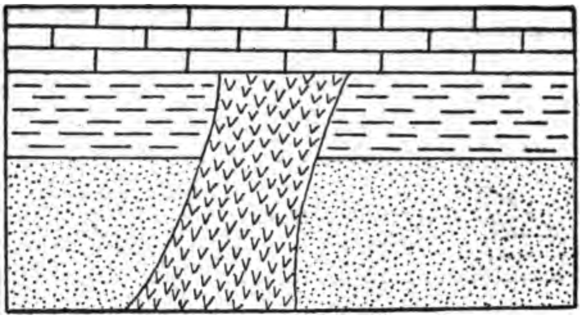

FIG. 40

10. Coarse-grained granites, schists, and gneisses outcrop over large areas in New England. Where were these rocks formed with reference to the surface? What inference can be drawn as to the amount of erosion in such a region?

11. Give the history of a region as recorded in this section, figure 41, (1) sandstone, (2) igneous rock, (3) shales, (4) igneous rock, scoriaceous where dotted, (5) tuff.

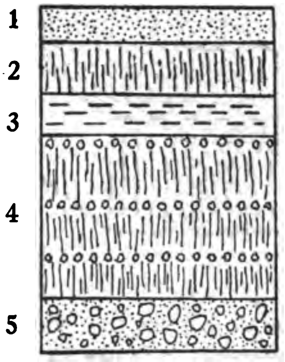

FIG. 41

12. Give the geological history of the region shown in the block diagram (Figure 42). What are the relative ages of the granite, sedimentary rock, and basalt?

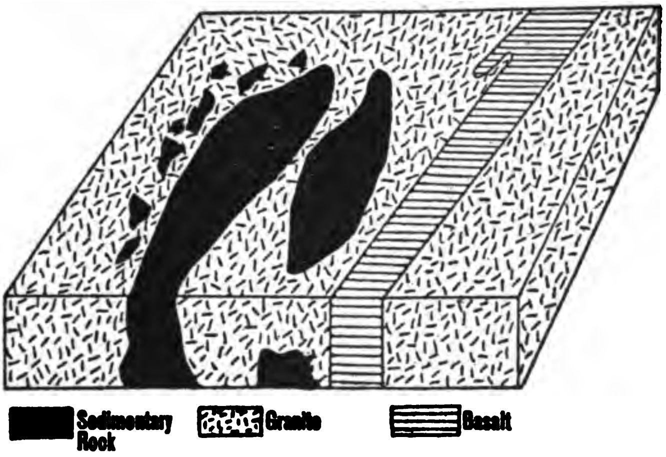

FIG. 42

13. Which of the igneous sheets in the accompanying diagram (Figure 43) are extrusive and which intrusive?

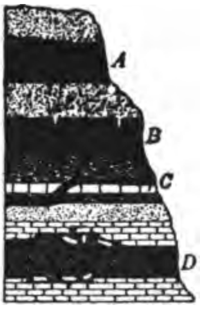

FIG. 43—AFTER NORTON, ELEMENTS OF GEOLOGY

14. Give the history of the region in which the section shown in figure 44 occurs. The black is igneous rock. Label all structures.

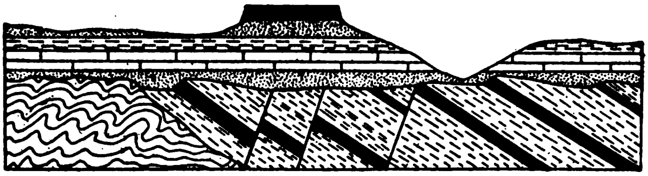

Fig. 44

15. Give the history of the region in which the section shown in figure 45 occurs and label all structures.

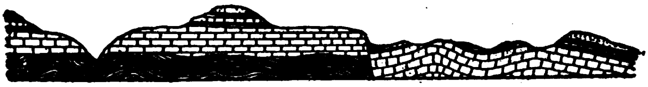

Fig. 45—After Dwerryhouse

16. From the following data construct a section which shall indicate the events given. Sandstone beds were formed in the sea and while still submerged were intruded by two sills. In the course of time emergence occurred which tilted the beds. The beds were then exposed to erosion for such a long time that they were base-levelled. Gradual submergence then permitted the deposition of (1) a basal conglomerate, (2) a shale, and (3) a limestone. At the end of this time the region was again raised above the sea.

17. Construct a section along the line A-B (Figure 46). The strata are horizontal.

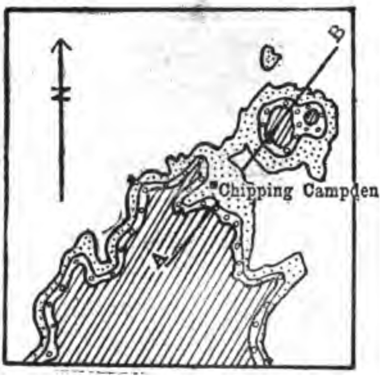

Fig. 46—After Dwerryhouse

18. What is the basis for the following statement concerning a region in Idaho? "Near the end of the Cretaceous Period great crustal movements raised the surface to an altitude of several thousand feet, rejuvenating the streams and initiating a period of rapid erosion, which by the end of Eocene time had reduced the surface nearly to the base level for the area. Late in the Eocene or early in the Oligocene this low land was raised to a height near the present summit level, a total uplift of about 10,000 feet. The streams once again became active agents in reducing the surface, the larger ones developing broad valleys, many of which received lava flows and lacustrine deposits in Miocene and possibly also in Pliocene time. Then followed another period of dominant erosion during at least the early part of the Pliocene. Valleys as much as 4,000 feet deep were carved in the Miocene rocks and later shaped by ice." U. S. Professional Paper 97, page 22, 1917.

19. From what evidence can one tell whether A-B in figure 47 is an unconformity (disconformity) or a bedding plane?

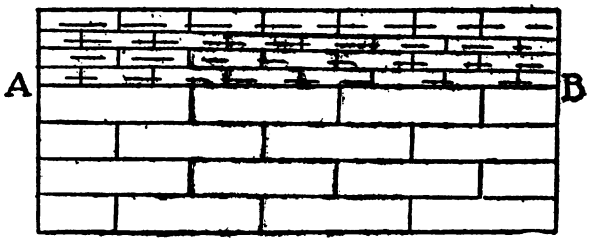

FIG. 47

20. The bands of Archean rocks, (ancient igneous and metamorphic rocks) between Ottawa and Georgian Bay differ from those of most other parts of the Laurentian region in the prevalence of limestones and marbles, which run as long, synclinal bands between igneous masses. How, in your opinion, would the presence of these sedimentary rocks be shown in the topography?

21. Name the structures shown in the following section (Figure 48) of a part of Arizona and give the geological history of the region in as far as it can be deciphered from this section. The black is igneous rock.

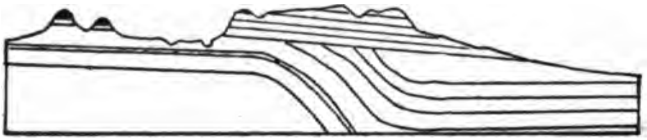

FIG. 48—MODIFIED AFTER U. S. GEOLOGICAL SURVEY

22. Give a brief account of the geological history of the region of which the section shown in figure 49 occurs. Label all structures. The black is igneous rock.

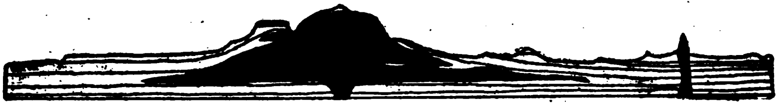

FIG. 49—MODIFIED AFTER U. S. GEOLOGICAL SURVEY

23. Construct a section along the line A-B of the geological map (Figure 50) to show the structure of the beds. A normal fault is shown and the arrows show the direction of the dip of the rock.

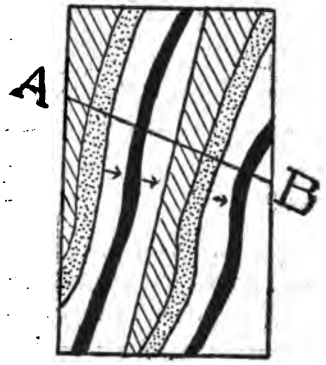

FIG. 50—MODIFIED AFTER RIES AND WATSON

24. What is the origin of the depressions on recently raised coastal plains in which lakes rest?

25. What lakes are formed by crustal movements (diastrophism)? Examples.

CHAPTER XIX

QUESTIONS ON EARTHQUAKES

1. A house constructed of stone was badly damaged by an earthquake shock, while another one nearby of the same construction and materials escaped with little damage. Give the possible explanation.

2. After the Messina, Sicily, earthquake the Italian Government made certain recommendations: (1) concerning the construction of buildings, (2) concerning the height of buildings in different parts of the city, (3) concerning the parts of the city on which no building should be erected. State in detail the reasons for these recommendations.

3. In the Avezzano, Italy, earthquake of 1916 there was great destruction of life and property. The high cost of quicklime was an important indirect cause of the loss of life. Explain.

4. An American man-of-war was lying at anchor in the harbor of a seaport which was shaken by an earthquake. After the shock had passed the white paint of the ship was found to be blackened. Explain.

5. Do earthquakes form faults? If so, are they large or small, and what are the favoring conditions? Construct a diagram to show this.

6. What are the characteristics of "earthquake topography"? Study the San Mateo, California, and Santa Cruz, California, topographic sheets and point out this topography.

7. An account of an earthquake appeared in a daily paper in which it was stated on good authority that at least 30,000 lives had been lost. From this brief statement tell the probable cause of the earthquake; if landslides occurred, where they occurred and why; what kinds of houses were demolished and why; where the greatest destruction was located.

8. Why do brick chimneys break off at the roof line during earthquake shocks?

9. In times of earthquake shock small houses may be shifted off their foundations by the horizontal jerk. How may this be obviated?

10. What is the best type of earthquake-proof residence?

11. What portions of San Francisco suffered most severely from the shock of 1906? What was the cause of the exceptionally heavy damage in these districts?

12. At the time of the California earthquake of 1906 some buildings of Stanford University were completely wrecked and many were injured but the Museum which was built of reinforced concrete suffered no serious damage. What was the reason for this immunity?

13. If one is on an alluvial flat facing a harbor during a severe earthquake what should one do as soon as the shock has passed?

CHAPTER XX

QUESTIONS ON LAKES

1. What types of lakes may be formed in connection with the development of stream valleys? Are they shallow or deep? Are they of economic importance? Give examples.

2. What types of lakes are formed as a result of glaciation? In what ways were their basins formed? Of what economic importance are lakes of this origin? Compare the lakes north of the Ohio River, with those south of it as to number, size, depth, and origin.

3. How are lakes formed in connection with the development of shores? Cite examples.

4. How may lakes be formed through the agency of drifting sand or of lava flows? Examples. How were some of the lakes of the semi-arid portions of western Nebraska and Kansas formed?

5. What is the common origin of lakes in regions of thick limestone? What is their size? Have they any economic importance? Examples.

6. Under what conditions do landslides form lakes? What may be the extent of such lakes and what is their economic importance?

7. What is the origin of crater lakes? Why can not a crater lake usually be drawn upon as a source of permanent water supply?

8. What is the origin of the depressions on recently raised coastal plains in which lakes rest?

9. What lakes are formed by crustal movements (diastrophism)? Examples.

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